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ABSTRACT

The computer can assist test construction in the following four ways: (1) storage or banking of test items; (2) banking of item attributes; (3) test construction; and (4) test printing. Automated Item Banking (AIB) is a computerized item storage and test construction system which illustrates these capabilities. It was developed, implemented, and evaluated for accuracy of estimates in an experiment with 1,502 airman trainees. The experiment involved determining item statistics on one group, constructing a test interactively, scoring the test on another group, and comparing the estimated and observed test statistics; particularly, the mean, standard deviation, and reliability of an interactively constructed test. These comparisons indicated that the estimation procedures were sufficiently exact to permit a test constructor to have knowledge of the characteristics of a test prior to administering it. The AIB system permits rapid, secure, and error-free construction; furthermore, its natural language commands permit user flexibility. Appendices discuss the technical aspects and operation of the AIB. (Author/CP)

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AIR FORCE HUMAN RESOURCES LABORATORY

AUTOMATED TEST ITEM BANKING

By

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May 1978

Final Report for Period January 1977 – February 1978

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A computer-based item storage and test construction system was developed, implemented, and tested for accuracy of estimates. The test consisted of determining item statistics on one group, constructing a test interactively, scoring the test on another group, and comparing the estimated and observed test statistics. These comparisons indicated that the estimation procedures were sufficiently exact to permit a test constructor to have knowledge of the characteristics of a test prior to administering the test.

PREFACE

This research was conducted under project 7719, Air Force Development of Selection, Assignment, Performance Evaluation, Retention and Utilization Devices; task 771915, Perceptual and Computer managed measurement.

The assistance provided during the course of this research by the Testing Branch of the Personnel Research Division is greatly appreciated.

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AUTOMATED TEST ITEM BANKING

I. INTRODUCTION

The high speed digital computer has proven to be an important labor saving device for the psychometrician. For two decades, tests and items have been analyzed with speed and accuracy, and the number and quality of item analysis programs have increased every year. With the relative cost of computer computations decreasing, automated item analysis has become the norm. Recently, adaptive aptitude and achievement tests have been administered on the computer (Bejar, Weiss, & Gialluca, 1977; Ree, 1977). These adaptive testing procedures have required computer manipulable item pools and sophisticated programming algorithms to facilitate item storage and retrieval.

An outgrowth of computer adaptive testing and item analysis is the computer storage of test items and interactive test construction. Lippey (1974) presents several alternative concepts of this "computer assisted test construction."

Test construction is a time-consuming and laborious task which requires the methodological searching of files of item cards and the selection of relatively few items from a large mass of items. During this search the items must be sorted and resorted and, as the number of items increases, so does the probability of not selecting the best available item. The selected items must be ordered by difficulty or in some other fashion and then edited for final form. Next, this final group of items must be typed and reproduced into booklets for experimental purposes. The experimental booklets must then be administered and scored. Finally, the test statistics must be computed and the appropriate norms developed.

During the test construction phase, the security of the test items, answer keys, and the test must be maintained. The method described in this report permits the interactive construction of tests and manipulation of banks of test items at a computer terminal. It is a system which permits maximum security by using computer files available only to specific users. The system permits a test constructor to search through a large number of items very rapidly and without the clerical errors frequently involved in manual searches. Test items may be printed several different ways. The system also provides the user with a stop and restart procedure and keeps track of items selected, their relevant characteristics, and how many more items are required to build the test. All these capabilities permit more rapid, secure, and error-free test construction.

II. THE SYSTEM

The computer can assist test preparation in the following four ways: (a) storage or banking of test items, (b) banking of item attributes, (c) test construction, and (d) test printing. Each of these capabilities is required for test construction.

The Automated Item Banking (AIB) system is comprised of three modules: (a) a text editor which permits the establishment and/or modification of item banks, (b) an item bank listing procedure which permits selected items from the item bank to be printed on the high-speed printer, and (c) an interactive test construction procedure which permits the interactive searching of an item pool, the construction of a test, and the estimation of test statistics.

The text editing processor is designed with a series of options which permit the interactive user to establish an item pool, modify items, change item statistics, modify or replace item stems or item-options, and obtain printed copies of specified items. It is useful for updating item banks and for adding items to existing item banks. The files created by the text editor are designed to be parsimonious of computer storage space and are easily modifiable by appropriate users but are secure against unauthorized tampering.

The listing procedure is used to provide printed copies of either all or a specified subset of the items and item statistics in an item pool. Printed copies of the items from the listing procedure are useful for purposes of proofreading, error detection, and transfer of the items to another facility or organization.

The test construction routine permits the interactive searching of an item pool and the selection of items. Operational or experimental tests may be built "on line" by specifying desired item statistics. A search based on either classical item difficulty (p) or latent-trait difficulty (b) attributes may be specified. As the text of an item is interactively presented on the computer terminal, the item statistics, keyed response, normative sample, and last operational use of the item are also presented. The item is then either accepted for inclusion in the test or rejected and another item found.

During test construction, the routine estimates test statistics for the subset of items selected and keeps track of the number of items initially requested and the number of items remaining to be selected. An option for suspending and restarting the test construction procedure is also provided.

Finally, the printing of the interactively constructed test is done on the highspeed line printer in one of three optional ways: the items may be printed in the order selected, sorted according to classical difficulty, or sorted according to latent-trait difficulty. See Appendix A for a detailed explanation of the theory of the operation of the system, and Appendix B for computer documentation.

The system's computer programs are written in FORTRAN and assembly language. All file handling is done in assembly level language to reduce overall program size. It is implemented on a Univac 1108 with level 32R2B of the Exec 8 executive system.

III. THE RESEARCH PROBLEM

In order for such an automated system to be of any value, it must be accurate, as well as fast. The following study was conducted in order to determine the accuracy of the estimation procedures. Of interest in this study were the comparisons between the estimated and actual values for the test mean, standard deviation, and reliability of an interactively constructed test.

IV. METHOD

Subjects

A group of 1,502 basic airman trainees at Lackland AFB, Texas, was randomly selected for this study. The subjects were randomly assigned to either the developmental group or the cross-validation group.

Items

The items were the Word Knowledge type culled from existing item files and were all of the same form. Each item consisted of a stem containing a word and five item options. The examinee was asked to select the item-option which most nearly means the same as the stem word. An example is presented as follows:

"Small means

1. sturdy.
2. round.
3. cheap.
4. little.
5. crisp."

Items of this type are frequently found in military selection and classification test batteries as well as in academic aptitude and vocational aptitude tests.

Using available item difficulty (p) and item-test phi coefficients, an experimental test was designed to cover the difficulty (p) range of about .20 to about .90 with the highest available phi coefficients in each difficulty level. An experimental test of 200 of these items was assembled and administered to the subjects in a counterbalanced manner with half the subjects beginning with item 1 and half beginning with item 101. The subjects were administered all 200 items in one continuous time period.

Item Calibration

The item responses from the developmental group were used to estimate the latent-trait item parameters (Urry, 1975), the classical item difficulty (p), and item discrimination (item-test biserial correlation) indices. From the group of 200 items, several were discarded due to poor item characteristics or due to defensible distractors. A final pool of 115 items was entered into the AIB system.

Automated Item Bank Tryout

A test outline was developed to emulate the structure of a proposed test. The AIB system was used to search the item bank for item difficulty (p) values between .20 and .90. Table 1 shows the distribution of desired p values.

Table 1. **Distribution of Item Difficulty Values Requested of AIB for the Experimental Test**

Item Difficulty	Number of Items Requested
.20 – .29	1
.30 – .39	2
.40 – .49	4
.50 – .59	6
.60 – .69	4
.70 – .79	2
.80 – .89	1
Total	20

The AIB system was activated, a p value search was initiated, and 20 items were selected. Using the printing option, the items and the estimated test statistics were output to the high-speed printer. These selected items were then identified in the 200-item experimental Word Knowledge test, and these 20 items were scored for the hold-out or cross-validity group.

V. RESULTS

Table 2 presents a comparison of the hold-out group calculated and AIB estimated characteristics for the 20-item AIB developed test.

Table 2. **Calculated and Estimated Test Values for 20 AIB Selected Items**

Test Statistics	Calculated (Based on Hold-out Group N = 751)	AIB Estimated
Mean Score	10.48	10.62
Standard Deviation	4.26	4.00
Reliability[a]	.80	.72

[a]A Coefficient Alpha measure of internal consistency.

VI. DISCUSSION

Comparisons of the estimated versus the computed statistics indicate that the procedures are accurate and permit the test constructor to build a test with desired psychometric characteristics.

All 20 items selected interactively were selected by an individual with no computer programming experience. The ease of use of the AIB system is in large part due to the use of natural language commands. In addition, the formatting or positioning of these commands on the computer terminal is inconsequential. The computer asks a question in plain English, and the user responds in plain English. User errors in responding are handled by displaying on the computer terminal the inappropriate command response and a list of the appropriate commands.

The AIB system operates rapidly and permits a high degree of user flexibility.

VII. CONCLUSIONS

The AIB system can be utilized to construct tests of known quality "on line." Use of this system can reduce storage of item cards, and proper storage of item banks on magnetic data tapes and/or microfiche can provide protection against loss. Input operation and the automated selection procedures are simple enough to be used by those without sophistication in computer programming or operation. The speed and flexibility of the AIB system permit the construction of tests in less time and with reduced security problems.

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APPENDIX A: TECHNICAL ASPECTS OF THE AUTOMATED ITEM BANK

The automated item bank permits two types of searches but always estimates the test statistics based in latent-trait theory. When a search is initiated, a b or p value is requested and an interval is created around that value. For example, if a p value of .50 is requested, an interval from .47 to .53 is created; then the vector of item p values is searched and the first item with a p value in this interval is displayed. If no item with a p value in this interval is found, then the interval is increased by a constant .03. Then the interval is searched again until an item is located or the interval is widened again and searched until an item is found, or until the p value interval is from .00 to 1.00, and the system issues an error message and shuts down. The same general procedure is followed for a b value search except that the constant is .10 and the termination bounds are set at −3.1 and +3.1.

When an item is presented for consideration by the test constructor, it may be accepted or rejected by answering the terminal prompt question with a natural language "YES" or "NO." An affirmative response includes the item in the tentative test, and a negative response sets the program to searching the item bank file again.

After the second item has been included in the test, a routine estimates the expected values for the test mean, variance, standard deviation, and test reliability for two groups of "pseudo subjects." Group 1 is defined as a full range sample of the mobilization population and covers the first to the 99th percentile. The second group is a restricted sample which runs from the 30th percentile to the 99th percentile of the same population. The 30the percentile was selected because it is about the lowest value encountered in Air Force enlisted recruits. It could be set to any other value in the program to reflect a different lower limit. This estimation procedure is accomplished by generating 5,000 unit normal random "ability estimates," θ, in the interval of about −3.0 to +3.0 and then using equation (1) generating the probability that a "subject" with that θ would pass the item. This is done for each "subject" across all the items in the test.

$$P(\theta) = c + (1 - c) + \left(1 + e^{(-1.7a\,(\theta - b))}\right)^{-1} \qquad (1)$$

where $P(\theta)$ is the probability of passing the item, a is the item discrimination parameter, b is the item difficulty or location parameter, and c is the lower asymptote of the item characteristic curve. See Birnbaum (1968) for a complete discussion of the 3 parameter logistic latent-trait model. The variance of subject scores is computed and also the item variance. From this information a Coefficient Alpha (Cronback, 1951) reliability estimate is computed. This procedure is repeated after each item is selected and when the test construction phase is completed. An estimate of expected percentile equivalent scores is computed using equation (2).

$$\text{Percentile} = Q(Z) + K \qquad (2)$$

where Q is the estimated test standard deviation, K is the estimated mean, and Z is the unit normal Z score corresponding to specific percentiles in the normal distribution.

The next process of the AIB is to update the item files with the number of the operational test constructed for those items used in the test (see Appendix B).

The last procedure of the AiB is to offer the test constructor a choice of output ordering of the selected test items, the actual test items, the final test statistics estimates, and the percentile equivalents.

APPENDIX B: OPERATION OF THE AUTOMATED ITEM BANK

1.0 **Item Banking Operations**

1.1 This automated banking and test construction system is designed for the UNIVAC 1100 series. It is currently implemented on the UNIVAC 1108 with EXEC 8 at level 32R2B.

1.2 The system must be used with previously catalogued item files, and each separate procedure is executed in the same manner with a processor call followed by the name of the item file.

@FILE.ELEMENT ITEMFILE.

1.3 Input errors cause the input prompt to be repeated along with an error message.

1.4 Termination of a run always causes an exit statement to be printed so that the operator knows the system has been successfully exited.

1.5 Any termination of a run prior to the completion of the requested action causes a file to be automatically catalogued for a restart at some future date.

1.6 Each item file should contain only one item type such as WORD KNOWLEDGE. Do not mix ability areas.

2.0 **Abbreviations used in item bank files.**

K = number of the correct item option
P = portion of examinees selecting keyed option
B = latent-trait difficulty or location parameter
D = median-split item test phi coefficient
RBI = item-test biserial correlation
A = latent-trait discrimination parameter
RPB = item-test point biserial correlation
C = latent-trait "guessing" parameter
SMPL = identification of item-analysis sample (see para 4 for number code)
TEST = Identification of operational test in which item last appeared (see para 3 for number code).

3.0 **SMPL – Identification numbers.** First number indicates operational test type. Decimal portion of number indicates which form of operational test.

3.2 Identification of Armed Services Vocational Aptitude Battery (ASVAB).

1.00 – ASVAB type items
1.01 – used in ASVAB One
1.02 – used in ASVAB Two
1.03 – used in ASVAB Three
1.04 – used in ASVAB Four
1.05 – used in ASVAB Five
1.06 – used in ASVAB Six
1.07 – used in ASVAB Seven
etc.

3.3 Identification of Enlistment Screening Test (EST)

2.00 – EST type items
2.01 – EST Form One
2.02 – EST Form Two

3.4 Identification of Electronic Data Processing Test (EDPT)

3.00 – EDPT type items
3.01 – EDPT Form One
3.02 – EDPT Form Two

3.5 Identification of Radio Operator Test (ROT)

4.00 – ROT type items
4.01 – ROT Form One
4.02 – ROT Form Two

3.6 Identification of Air Force Officer Qualifying Test (AFOQT)

5.00 – AFOQT type items
5.01 – AFOQT Form M
5.02 – AFOQT Form N
5.03 – AFOQT Form O

4.0 List of Acceptable Numbers for SMPL

4.1 Identification of ASVAB Samples

1.01 – unselected basic airmen
1.02 – unselected male basic airmen
1.03 – unselected female basic airmen
1.04 – unselected White basic airmen
1.05 – unselected non-White basic airmen

4.2 Identification of EST Samples

2.01 – unselected basic airmen
2.02 – unselected male basic airmen
2.03 – unselected female basic airmen
2.04 – unselected White basic airmen
2.05 – unselected non-White basic airmen

4.3 Identification of EDPT Samples

3.01 – unselected basic airmen
3.02 – unselected male basic airmen
3.03 – unselected female basic airmen
3.04 – unselected White basic airmen
3.05 – unselected non-White basic airmen

4.4 Identification of ROT Samples

4.01 – unselected basic airmen
4.02 – unselected male basic airmen
4.03 – unselected female basic airmen
4.04 – unselected White basic airmen
4.05 – unselected non-White basic airmen

4.5 Identification of AFOQT Samples

5.01 – unselected OTS students
5.02 – unselected ROTC students
5.03 – unselected Category I and II male basic airmen
5.04 – unselected Category I and II female basic airmen
5.05 – unselected Category I and II White basic airmen
5.06 – unselected Category I and II non-White basic airmen

5.0 Operation of Item Banking System on UNIVAC 1108

5.1 Item banking is maintained by the AFHRL/PES DS* interactive computer user group. All files are maintained as public, but they do require the qualifier DS*.

5.2 Processor call for item banking.

@DS*PES.IBANK FILENAME. (FILENAME supplied by user)

Machine Response

ENTER TEST ID NUMBER

Refer to paragraphs 3.2 through 3.6

NOTE: Test ID 99.99 may be used for learning or demonstration purposes and will not cause update of item files.

Machine responds to test ID with

ITEM POOL CONTAINS NNN ITEMS

If item pool is empty or in error, operator is advised.

TYPE 1 FOR A P-VALUE SEARCH

TYPE 2 FOR A LATENT-TRAIT B-VALUE SEARCH, ENTER @EOF TO EXIT PROGRAM.

Values other than 1 or 2 will cause error message to be printed and the search type question to be repeated.

If a restart file exists from a previous run, the terminal responds.

RESTART FILE AVAILABLE,

DO YOU WANT TO RESTART (Y or N)?

A Y or N for Yes or No response is acceptable. A restart permits an unfinished previous run to be completed.

Machine Response

ENTER NUMBER OF ITEMS REQUESTED, MAY NOT EXCEED 200.

Numbers less than 1 or greater than 200 will cause question to be repeated.

Machine Response

YOU HAVE SELECTED nnn ITEMS FROM NNN REQUESTED. ENTER WANTED P VALUE (or ENTER WANTED B VALUE).

Input is checked for range. P-value range is .01 to .99. B-value range is –3.0 to +3.0. Machine responds to incorrect P value or B value by soliciting value again.

Sample response to P-value search of P = .11.

OCCIDENTAL MEANS

1. UNEXPECTED
2. UNUSUAL
3. SUITABLE
4. WESTERN
5. PERTAINING TO LIFE

K = 4 P = .11 B = 2.20 D = .30 RBI.85 A = 1.64 RPB = .75 C = .12 SMPL = 1.00 TEST = 1.00

DO YOU WANT THIS ITEM?

May be answered YES or NO or @EOF

A response of @EOF will cause a file to be created for later restart. This restart file is catalogued by user identification number.

If YES, machine responds by soliciting next P or B value. If NO, item bank is searched for another possible item. After the second item is selected, estimations of mean score, variance, standard deviation, and reliability are computed and presented. The following message is also presented:

PRESS TRANSMIT TO CONTINUE--

If the search procedure is unsuccessful at finding an item within a prescribed interval about the requested P or B value, a request for a new value will be issued.

After all the items have been found and accepted by the user, the following message is issued by the terminal.

ITEMS ACCEPTED ARE:

This message is followed by a list of the item numbers. The following question is then issued.

DO YOU WANT A HARD COPY OF THESE ITEMS?

May be answered YES or NO.

A response of NO causes the system to be exited with no change to item file. The following message is then printed on the terminal.

ITEM BANKING EXITED
NORMAL END V 2

A response of YES is followed by

ENTER SELECTION OPTION TO BE USED FOR PRINTING THE HARD COPY LISTING.

1 = LISTING AS SELECTED
2 = SORT ON P VALUES
3 = SORT ON B VALUES

After the option is selected, the item file is updated to show number of the test created for those items selected. The items are then sent to the high speed printer and the following message is printed on the terminal.

ITEM BANKING EXITED
NORMAL END V 2

This statement completes the interactive construction of a test.

5.3 Processor Call for Editor.

@DS*PES.EDIT FILENAME. (FILENAME supplied by user)

Machine response

EDIT COMMAND LIST:

A. . . . . .APPEND TO THE ITEM BANK
Blank. . . . . .GO TO NEXT ITEM
Exit. . . . . .TERMINATE THE RUN
F < N > or F all [< N >] . . EDIT ONE OR ALL "F" VALUES
G < N >. . . . . .GO TO ITEM "N"
H. . . . . ."HELP" (DISPLAY THIS LIST)

PRESS TRANSMIT FOR MORE INFO

Machine response

COMMAND LIST:

K < ANS > . . . . . .CHANGE ITEM KEY VALUE
N. . . . . .GO TO NEXT ITEM
P < N > R. . . . . .PRINT ITEM "N"
R < N > OR R . . . .RETYPE ITEM "N"
T < N > OR T ALL . .EDIT ONE OR ALL TEXT LINES
Y. . . . . .ONE LINE HELP

PRESS TRANSMIT TO RETURN TO EDIT MODE.

Machine response

ITEM POOL CONTAINS NNN ITEMS

or

ITEM POOL IS EMPTY

then

(nnn) EDIT COMMAND?

The nnn is the item number. The operator then gives the appropriate edit command.

To enter an item into the pool use the "Append" command and answer the machine prompts. Note that only the text may be alpharmeric; all other input must be numeric.

To change a line of text in the item on the screen use "Tn" when n is the line number.

To change an F value use "Fn" when n is the sequential number of the F value. These are the item statistics and item parameters stored with the item. See paragraph 7.0.

To change the keyed item option use the "K" command. "K4" will change the keyed item option to 4.

To change the entry question use the "R" retype option and answer terminal prompts as in the "A."

The ' Y" command or one line help causes the following to be printed.

ENTER A, BLANK, E, F, G, H, K, N, P, R, T, or Y.

To terminate the file editing or building use the "EXIT" command. The following will be issued if the editor is successfully exited.

END ITEME. ITEM POOL FILE CONTAINS nnn ITEMS.

5.4 Processor Call for Listing Portion of or Entire Item Bank File.

@DS*PES.ITEML FILENAME. (FILENAME supplied by user)

Will list entire item bank file.

@DS*PES.ITEML FILENAME., A–D, J–M, R–X, Z

Will list items A–D followed by J–M, R–X, and finally Item Z.

At the end of this routine, the program will issue the following message:

END ITEML

This program may be used interactively, as part of a batch run or with the Univac breakpointing procedures.

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